advanced buildings

Rooftop Unit HVAC Efficiency: *Repair, Retrofit, Replace*

A Framework for Energy Savings in Unitary Rooftop Equipment

nbi new buildings institute

This primer describes energy savings opportunities and context for packaged rooftop units (RTUs) for building owners, managers, operators, engineers, contractors and utilities. RTUs are ubiquitous in commercial spaces but are also a difficult market to reach. Analysis shows many opportunities for savings over code for new and existing RTU programs. In addition, entities that conduct pilot projects or evaluations of their own RTU program measures can leverage the results with a standardized analysis protocol. This will greatly aid in establishing more appropriate program incentives and marketing numbers that will support efficiency activities.

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Introduction

This primer provides an overview of the challenges, scope and solutions to improve the efficiency of existing unitary heating and cooling equipment, commonly known as rooftop units (RTUs). We begin with a discussion of market size and examine evidence of how RTUs fail resulting in lower efficiency. To assess how utilities are currently pursuing efficiency in RTUs, we include findings from a survey of over 120 existing major utility efficiency programs targeted at RTUs and what aspects of the RTU efficiency they address.

The measures that influence RTU performance are often described by their product names or monikers that have developed over time. To simplify the landscape of what options are available we organize the most common measures into a framework that addresses the level of invasiveness: repairing, retrofitting, or replacing the RTU and its components, as well as what components are affected—either the equipment outside the facility (usually on the roof) or the equipment inside the facility including ducts, controls/thermostats and associated sensors.

With this Indoor/Outdoor, and Repair/Retrofit/Replace framework established we describe the measures that fall into these categories with a broad presentation of what occurs, the relative costs and savings, a highlight of the anticipated cost-effectiveness, and any programmatic best practices and notes.

Calculating energy savings and establishing justification for a program to a regulator presents a challenge. One must find enough data, especially data specific to the climate zone of the area, to establish a basis for incentives. For RTUs this is complicated by the weather dependency of RTU performance. Savings results for a test in Oregon are not relevant to a test in Chicago. This results in redundant testing by various entities. New Buildings Institute (NBI), working with the Bonneville Power Administration (BPA), has identified a method for normalizing performance data to improve translatability between climate zones. The use of a single methodology by many testing entities results in a leveraged data set that bolsters the case for RTU efficiency programs and improves the accuracy of incentives.

Lastly we discuss industry organizations and efforts that are underway to better unify the approach to RTU efficiency. There is tremendous opportunity for savings and advancement nationwide.

RTU Background

For over 10 years state energy organizations, public and investor-owned utilities and regional organizations, building owners, managers, operators, engineers and contractors have examined methods for improving the in-field operating efficiency of the class of lighter commercial unitary heating, ventilation and air conditioning (HVAC) equipment commonly known as RTUs.

RTUs provide heating and cooling combined with ventilation air and are a commonly used technology in commercial buildings. Upfront costs, installation, controls, and maintenance are well understood. In a world increasingly driven by speed and reducing overhead in construction and operation, the RTU is an ideal solution for many owners and managers of commercial buildings.

While this market paradigm is not ideal for energy efficiency, it does present an opportunity to access energy savings through modifications to existing RTUs. This primer examines some of these methods, their relative costs and impacts, as well as best practices in analyzing energy savings. NBI has invested considerable time and resources in identifying leading best practices in the industry.

HVAC and RTU Research

NBI conducts deep technical analysis of emerging products and protocols for efficiency in RTUs. Some examples of recent work include:

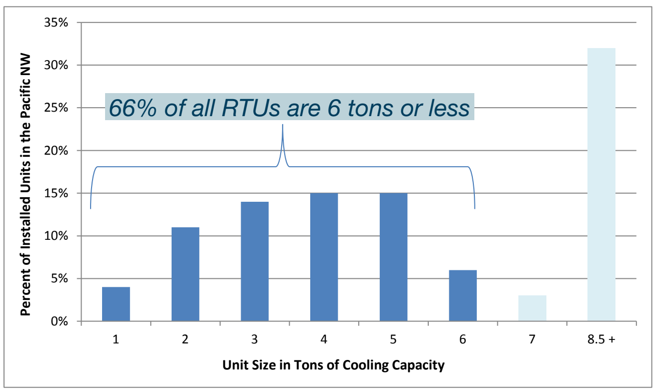
- Creation of the first Small Buildings HVAC Design Guide–2003
- Testing of early generation evaporative rooftop HVAC equipment–2005
- Development of improved economizer sensor with the NW Power and Conservation Council's **Rooftop Unit Working Group** and **Honeywell**–2008
- Significant input to development of an advanced digital economizer controller–**Honeywell JADE W7220**
- Creation of the **RTU savings protocol and calculator** with the NW Regional Technical Forum–2009
- Creation of the NBI Laboratory (NBIL) for advanced RTU analysis–2011
- Testing the US DOE High Performance RTU Challenge unit: Daikin McQuay Rebel–2012
- Testing of direct and indirect/direct evaporative HVAC RTU sidecar units–2012-13

NBI shares results and facilitates the collaborative analysis of data to promote advanced measures and design strategies for HVAC systems and HVAC-related public policy objectives.

This has led to significant involvement by NBI staff in the following:

- Continuing partnership with the Consortium for Energy Efficiency (CEE)
- Leadership with the startup team that created the **Western HVAC Performance Alliance**, a key stakeholder group with regulators, utilities, HVAC industry partnering–2009
- Leadership in the successful Rooftop Unit Fault Detection and Diagnostics Mandatory Measure Project in the California 2013 Title 24 building energy standard–2011
- Leadership with the NW Energy Codes Group in proposing the Rooftop Unit Fault Detection and Diagnostics Mandatory Measure in the 2015 International Energy Conservation Code. It is expected that the International Green Construction Code will adopt the same measure.

Figure 1: Percent of NW Installed RTUs by Size



Source: Northwest Energy Efficiency Alliance Commercial Building Stock Assessment.

RTUs in Commercial Buildings

Research demonstrates what any aerial view of commercial buildings will attest: RTUs are a very common choice for air conditioning and heating in small to medium-size buildings (50,000 SF and below) and larger one-floor buildings like retail big box stores or warehouses in the U.S. The Energy Information Association in 2003 found that approximately 46% of commercial buildings use RTUs, accounting for 60% of total floor space.

A frequent approach in smaller buildings is to use a "one-per-zone" design where each temperature zone gets a thermostat and an RTU to serve it. This design preference shows up in the frequency of RTU size by cooling capacity, expressed in 'tons' of cooling (a ton is equivalent to 12,000 Btu/hour of cooling capacity). Data collected from the Pacific Northwest reveals the frequency of RTU size by cooling capacity tonnage. The majority of units are six tons or smaller, creating cost constraints that impact feasible efficiency measures. Data from the Pacific Northwest shown in Figure 1 supports this size distribution assessment.

Table 1: RTUs an aging fleet

51% of the units have been on the roof for over a decade!

Age category		Under 5 tons	5 to 10 tons	Over 10 tons
		44%	36%	20%
0 to 4	17%	30,000	24,000	14,000
5 to 10	32%	56,000	46,000	26,000
10 to 19	35%	62,000	50,000	28,000
20+ years	16%	28,000	23,000	13,000

Source: NWPPC 6th Regional Power Plan

We know from survey data that RTUs are an aging fleet. Data from the California Energy Commission (CEC) and the Northwest Power and Conservation Council's 6th Power Plan show that more than half of all RTUs are at least 10 years old.

As RTUs age they begin to malfunction and degrade in performance. Unless there is an occupant complaint, many RTU-based HVAC systems do not receive any further maintenance than an occasional change of air filters. These complaints are typically driven by temperature discomfort, but many problems can occur which do not jeopardize comfort and so go unidentified. These can cause the RTU to use far more energy than is needed.

RTU Performance Degradation

According to the DOE, older inefficient commercial RTU air conditioning systems are common and can waste from $1,000 to $3,700 per unit annually, depending on building size and type. So where are the failures occurring that cause unnecessarily high energy usage?

Field work conducted by NBI and others reveals some of the most common equipment failures. These studies allow for two broad conclusions:

1. **Most RTUs Operate Inefficiently and Have Equipment Problems**

   Operating inefficiently means the RTU uses more energy than necessary to provide conditioned air. This could include many specific problems, but certain general areas are:

   - Outside air/economizer dampers are malfunctioning or broken
   - The refrigerant system is improperly calibrated
   - The control system is incapable of optimizing operation
   - Leaks and broken equipment allow too much outside air to enter the building
   - Over ventilation

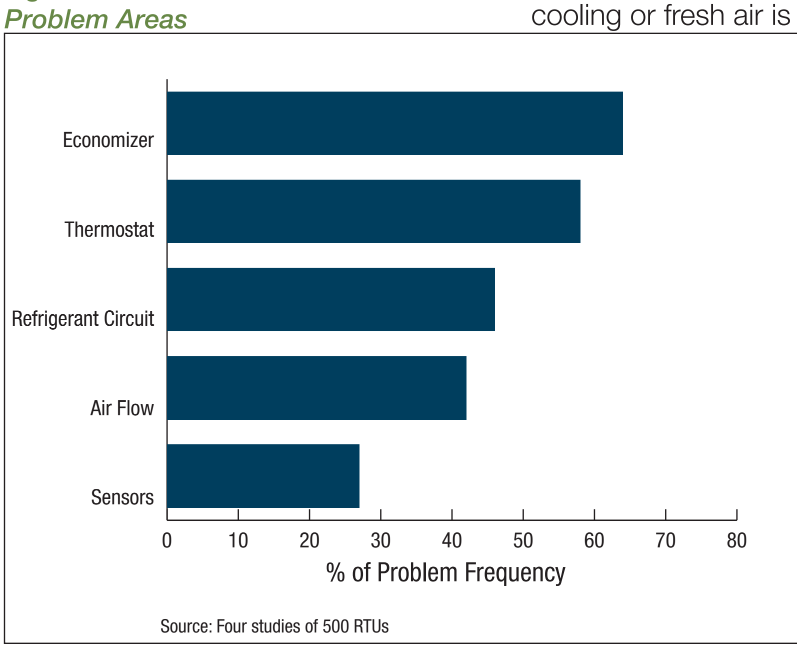
2. **Many RTUs Operate Unnecessarily**

   Unnecessary operation means that even if operating efficiently during regular hours, the unit may be running at times when no heating, cooling or fresh air is necessary. Causes could be:

   - Thermostat settings are not correct or monitored
   - Sensors are out of calibration
   - Controls are too simple

When examining data more specifically, using studies from NBI and others, a number of findings were clear. Figure 2 shows a distribution of detected problems in a combination of studies. Approaches to repair, retrofit and replacement must address the most common problems and prevent recurrence.

Figure 2: NW and California RTU Problem Areas



Utility Incentives and Rebates

A market survey conducted by NBI of 143 major utility and state programs for commercial efficiency shows many utilities are not accessing the savings opportunities in RTUs outside of providing modest incentives for a higher efficiency replacement RTU[1].

The market survey found 88%, or 126, of programs offer rebates for measures directly targeting RTUs. Of these offerings, the majority of programs offer incentives for replacement RTUs based on Air-conditioning, Heating & Refrigeration Institute (AHRI) ratings.[2] Of the 126 programs offering RTU incentives, 90% have incentives that range from $10 per ton to a maximum of $500–$600 for a 5-ton unit based on specific ratings or calculations. Many programs reference the Consortium for Energy Efficiency Tiers of performance which provide a simple classification based on performance ratings. Because the cost of a new 'code-level' 5-ton RTU can be around $5,000 and prices for high performance units are higher, an incentive of 10% or less may not be sufficient to impact the market.

The program incentives and frequencies are summarized in Table 2. The categories are based on the descriptions of measures described later in this primer. Of course, programs vary by region. Some climates are not suitable for certain measures due to high humidity in the summer or because the summer is too short for the measure to be effective at energy reduction.

Programs for variable speed drives (VFDs) and electrically commutated motors (ECMs) typically exist at many utilities but are targeted at either large, built-up HVAC installation fans (as opposed to small unitary RTUs) or refrigeration equipment motors. The category "Advanced RTU Controllers" in Table 2 refers to controllers suitable for unitary equipment that provide variable control of fan speeds (and potentially compressor speeds) and outside air dampers while providing Demand Controlled Ventilation (DCV) and fault detection. These programs are few in number and are not the same as traditional VFD incentive programs.

The landscape of RTU programs is driven by regulatory procedures and ongoing research. Efficiency programs work hard to design incentives based on existing and continuing research and must take into account what can be justified to regulators. These processes require a high level of capacity to maintain availabilty of system analytics which can aid greatly in this effort.

Table 2: RTU Programs Survey Results

	Number of Programs	Percent of Total	Typical Incentive
All Surveyed	**143**		
RTU Specific Programs	**126**	**88%*****	
Repair			
RTU Maintenance	20	16%	Flat amount from $50 to $1250 per unit
Thermostats and Sensors Check	12	10%	Often part of 'RTU Maintenance'
Retrofit			
Add Economizer	27	21%	Flat amount from $200 to $250
Duct Sealing	7	6%	Per SF or per CFM amount*
Supply Fan ECMs	0	0%	No specific programs**
Advanced RTU Controllers	2	2%	Still an emerging technology with a huge potential. See section below.
Demand Controlled Ventiliation	20	16%	Incentive dollars per SF or per CFM
Thermostat or EMS Upgrade	34	27%	Flat amount from $20 to $150
Other	14	11%	Includes EMS, ERVs, and specific products
Replace			
New Equivalent High Efficiency RTU	114	90%	Incentive based on AHRI rating: Ranges from $10 to $125 per ton
Complete Redesign	n/a	n/a	Falls under New Construction incentives
Evaporative RTU	n/a	n/a	No data

* square feet (SF) and cubic feet per minute (CFM)

**Incentive programs for ECMs do exist but do not offer incentives specifically for RTU supply fans.

***The percentages in the table don't add up to 100% because some programs have multiple incentive categories.

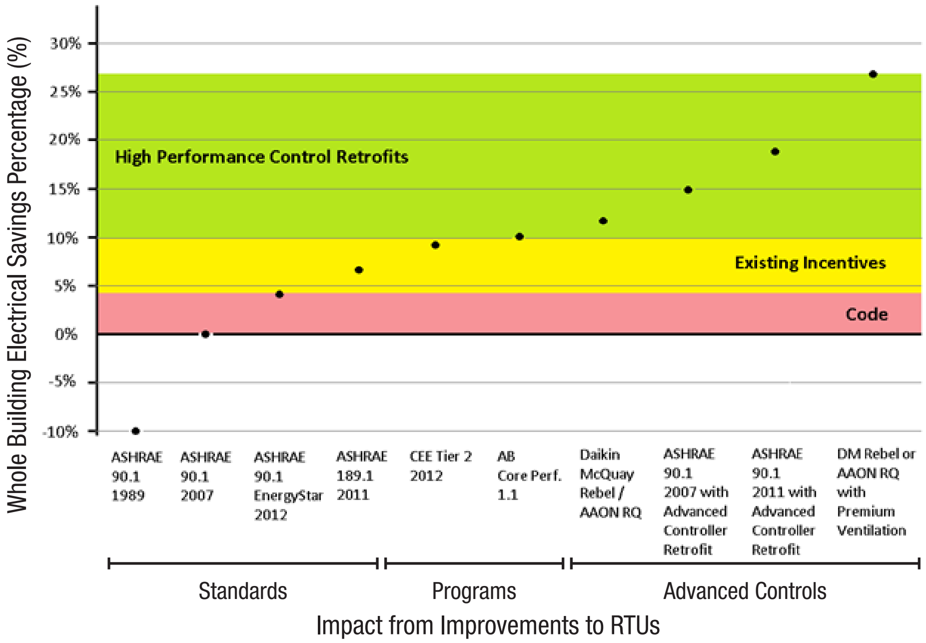
1. This does not include 'custom' programs which allow for any type of upgrade that is incentivized based on performance
2. Energy performance is rated by the American Heating and Refrigeration Institute (AHRI) which provides ratings of Energy Efficiency Ratio (EER) and Seasonal Energy Efficiency Ratio (SEER). Also used is the Integrated Energy Efficiency Ratio (IEER) is a measure of effectiveness at less than full load.

Potential Savings Still Available

As code baselines get stricter there is a perception that savings are drying up for many measures, including those for RTU programs. This perception is exacerbated by the fact that many RTU programs use AHRI ratings to determine unit eligibility and incentive levels. Those same AHRI ratings are typically used in energy codes to establish minimum performance requirements.

Despite the tightening requirements, there are still significant savings on the table for programs in the RTU space. This is because many measures address areas of efficiency for the RTU that are not impacted by the level of AHRI rating. The AHRI ratings address the efficiency of the refrigeration loop at specific conditions, but many performance issues are unrelated to the refrigeration loop. These include power needed to provide ventilation air, the ability to use free cooling, advanced control strategies and fault detection.

Figure 3: RTU Capability per Certain Standards



Consider the analysis of a two-story office building using energy modeling and supplemented by data from Pacific Northwest National Laboratory's (PNNL) work with control analysis. Figure 3 compares building energy use changes for different baselines compared to a building with RTUs that adhere to ASHRAE 90.1 – 1999. As codes advance in time a certain level of savings is achieved through improvements in ratings. Then the existing 'like-for-like' RTU incentive programs are considered, resulting in additional but modest savings. Using PNNL's calculator, certain retrofit control products are considered and savings increase dramatically. Couple this with more climate-specific design, and the possibility for significant savings is realized.

Accessing These Savings

The measures attempt to address the well-known failure mechanisms and shortcomings of RTUs in the field. The incentives paid by utilities, states and other energy efficiency and green building programs for these measures amount to a few hundred dollars and are often too small to be of interest to a particular contractor or owner. Emerging research is showing much greater opportunities in RTUs both in replacement units and by examining common areas of failure and new ways of improving efficiency in ways that aren't captured by standardized testing.

Those interested in developing programs to access these savings should:

1. Reevaluate current RTU programs and see what other approaches might be considered for their region.

2. Access existing research and work with utility personnel in areas that have programs or pilot projects underway or completed.
3. Consider a pilot program to establish savings to your regulators using this guidance on measures and analysis.
4. Join national initiative efforts such as Consortium for Energy Efficiency and DOE's Advanced RTU campaign.
5. Identify partners to facilitate data analysis that will result in defensible projections of savings for regulators.

Non-Energy Benefits

Owners and managers of commercial buildings with RTUs often have tenants that pay the electrical bill. This owner/tenant split incentive results in cases where owners and managers do not see the value of the work in dollar savings.

One method for counteracting this problem is to highlight non-energy benefits: i.e. features that provide value directly to the owner or manager by increased control over the site or increased ability to attract and retain tenants. Measures that provide increased control and monitoring to either the owner or tenant can yield this value and result in greater program penetration.

Some measures discussed in this primer provide internet connectivity and remote control over settings that owners and managers can use to track properties. Other features provide advanced scheduling and controllability or fault detection to tenants that may improve tenant retention. These upgrades can also increase facility valuation and translate into financial benefits for the owner or manager.

Other measures can reduce runtime on the compressor or other components, leading to increased RTU lifetime. This is also of real financial value for the owner. Although we cannot calculate an exact dollar value on each of these non-energy benefits, these features can be highlighted as part of a program to make it more compelling.

Ducts, Zoning and Lockouts, and the Building Envelope

Of course, not all energy usage problems are related to the RTU equipment or its controls. System design, installation, commissioning and the characteristics of the zone that it serves all influence the RTU's ability to operate efficiently. If the zone being served has a lot of infiltration or the ducts are poorly designed, then the RTU will work much harder to meet the set point temperature than a similar RTU with the same interior loads but with well-designed, well-sealed ducts and a good building envelope.

Outside of duct design and sealing, building and system design related issues can be addressed during new construction or major renovation. We discuss this in the 'Replace' section, but additional resources may be consulted at the left.

Design Resources:

NBI HVAC Design Guides:
http://newbuildings.org/hvac-resources

ASHRAE Small Building Design Guides:
https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides

NBI RTU Research:
http://newbuildings.org/hvac

Advanced Buildings
http://www.advancedbuildings.net/

The RTU Efficiency Framework

Using primary and secondary research, NBI has identified savings opportunities for RTUs with examples from energy efficiency and green building programs and data from projects and modeling analysis. A simple framework of measures is used to organize the approaches to address RTU efficiency. These are the three “Rs”:

Repair	Incentivizing maintenance personnel to visit a site and make standardized maintenance upgrades to a particular RTU and/or controls.
Retrofit	Adding a new component to an RTU, its components, or controls, to improve the thermodynamic operation, enable advanced or improved functionality or connectivity, or add diagnostic capability.
Replace	Completely remove existing RTU/controls and replace it with a higher efficiency unit or completely change the HVAC design approach.

Measures that fall into these categories apply either to the RTU equipment **outside** the building (typically on the roof) or to mechanical components or controls and sensors **inside** the building. This Primer Guide discusses measures in terms of ‘Inside’ and ‘Outside’ solutions.

Inside	Inside the building, the RTU thermostat, duct work and additional sensors are designed to maintain comfort based on occupant work schedule. Measures to improve performance include repairing and recommissioning the controls, installing a remotely monitored thermostat system, addressing duct leakage and installing lockout controls for doors and windows.
Outside	The heating, cooling and ventilation unit itself is typically on the roof. This label refers to repairs and measures that improve this RTU so that it delivers requested cooling (or heating) more efficiently.

In this way measures can be better understood in terms of how they address the typical problems that occur in RTUs. Within each category there can be more than one measure.

In the next section we provide some data and findings for different measures that fall into these categories. The categories are inherently linked and interdependent with training and education of both the workforce and the customer. Without aware end-users along with skilled HVAC contractors and technicians, required equipment maintenance is too often neglected, retrofits are not installed properly and replacement equipment is likely to be oversized (matching the oversizing of the original equipment) thereby repeating the downward efficiency cycle.

SUMMARY OF STRATEGIES

Table 3: Summary of Strategies for Rooftop Units Efficiency—Repair, Retrofit and Replace

Summary of Strategies: Measure Savings Expectations and Cost Effectiveness

This guide presents strategies and measures to help direct the efficiency efforts and programs of building owners, managers, operators, engineers, contractors and utilities. Table 3 summarizes the measures by group—Repair, Retrofit, and Replace—and divides measures into Inside and Outside categories within each group. The table also provides a simple assessment of the cost, savings, and cost-effectiveness of each measure or strategy. This broad view can guide the selection of areas of interest, depending on existing programs and incentive levels.

Short sections on each measure provided in this primer have descriptions and the status of program activity if available. The next section addresses RTU measures and strategies in more detail.

Repair	Measure	More Info	Cost	Savings	Cost Effectiveness
Outside	RTU Maintenance	Page 10	Low	Medium	High
	Fault Detection and Diagnostics	Page 11	Low	Medium	High
Inside	Thermostats, Sensors, and Controls	Page 12	Low	Mixed	High
Retrofit	**Measure**	**More Info**	**Cost**	**Savings**	**Cost Effectiveness**
Outside	Advanced Variable Speed Controls	Page 14	Medium-High	High	Medium
	ECM for Supply Fan Motor	Page 18	Medium	Medium	Medium-Low
	Air-Side Economizer	Page 18	Medium	Medium	Medium
	Evaporative ‘Side Car’ Unit	Page 19	Very High	High	Low*
	Evaporative Condenser Pre-Cooling	Page 20	Very High	High	Medium-Low*
Inside	Advanced Wireless Controls and/or EMS	Page 18	Medium-Low	Medium	Medium
Replace	**Measure**	**More Info**	**Cost**	**Savings**	**Cost Effectiveness**
Outside	High Efficiency RTU	Page 21	High	High	Medium
	HVAC System Redesign	Page 22	N/A	N/A	Medium-Low
Inside	HVAC System Redesign	Page 22	N/A	N/A	Medium-Low

* *Excludes humid climates*

REPAIR

Outside Equipment

		Repair	Retrofit	Replace
Outside - Repair	Outside	●		
	Inside			

Repair covers approaches considered 'maintenance' rather than 'service' of the units and systems. The term 'service' is used to describe the minimum approach needed by owners and contractors to keep equipment operating for occupant comfort (such as filter changes and complaint responses). The term 'maintenance' is used to describe a more comprehensive approach aimed at optimizing and maintaining performance of the equipment and the entire system.

Cost Effectiveness	High
Cost	Low
Savings	Medium

RTU Maintenance

Outside repair programs perform maintenance using a trade ally to visit a customer and verify that the unit is operating to the manufacturer's specifications and make small necessary repairs. This may include a multi-year program of continuous service. Programs for RTU maintenance are surprisingly infrequent: only 9% of major utility RTU rebate programs surveyed provide incentives for RTU maintenance. The scope of the measure involves having a contractor provide specific services, such as:

- Coil cleaning
- Fan Maintenance
- Refrigerant charging and leak repair
- Economizer testing and repair
- RTU controller replacement
- Economizer control upgrade
- Replacement damper motor
- Thermostat replacement and schedule adjustment (see Inside Repair below)

Source: CQM measures from ***Performance Alliance website***

Savings and Costs

RTU maintenance programs typically charge a flat fee per visit or sometimes offer a per-ton incentive.

RTU maintenance program savings are generally accepted to be high but can be difficult to evaluate in the field due to the influence of many factors on the RTU performance. Most field data seems to confirm savings expected from models, but contractor performance varies widely. This variability can jeopardize savings. In California, studies have provided mixed results, and savings are smaller than expected. There are some disputes over analysis methods and contractor procedure as well as the acceptable baseline assumptions for regulators.

The correction of code non-compliance 'problems' with RTUs can also impact savings and may result in more energy usage. In some cases adjustment of ventilation air settings or damper repairs can lead to increased energy use.

Program and Project Experience Notes

A recent California survey found that 58% of eligible contractors were unaware that energy efficiency and green building programs and incentives existed. But the same study found that those who had participated reported more satisfied clients and greater uptake of new clients as a result.

The same study also reported that about 75% of contractors were interested in training resources from such programs with a high priority placed on jobsite-based training. Online courses were not considered as valuable. The following lists provide program and project experience insights:

- Provide ongoing contractor support and **training**. Marketing and outreach of the programs is important.
- Programs should be based on **ACCA/ANSI Standard 180** which standardizes maintenance procedures.
- Consider off-the-shelf model programs such as **PECI's Continuous Quality Maintenance** and **AirCare Plus** programs which have a proven track history.
- Use the repair program to make the owner/contractor contact as a conduit to upgrade to bigger changes and savings through retrofits and replacements.
- It may be cost-effective to consider a simple controls retrofit as a standard part of a repair program. More specifically, the lower cost simplified controls. We discuss two products in the Outside Retrofit section that improve the ability to set the outside air fraction, implement demand controlled ventilation, and implement a simple fault detection and diagnostics (FDD) system.

Fault Detection and Diagnostics

Cost Effectiveness	High
Cost	Low
Savings	Medium

Fault Detection and Diagnostics is a method that specifies how a piece of monitoring equipment should automate detection and conveyance of messages that alert users (tenants), vendors, or contractors to RTU maintenance issues or faults. FDD is moving into energy codes as a requirement rather than a measure for RTUs. The FDD capabilities will enhance the retrofit and repair options for RTUs as retrofit equipment becomes part of the equation.

FDD requires that control or monitoring equipment detect and flag certain conditions such as:

- Air temperature sensor fault

- Low or high refrigerant charge
- Compressor short cycling
- Economizer fault

Savings and Costs:

Costs for FDD vary significantly. The savings come from increased persistence of design efficiency operational savings. The California Title 24 energy code adoption process requires cost-effectiveness, and the FDD requirement was deemed cost-effective. The annual savings across all California climate zones were determined to be 299 kWh and 35 therms for a 54,000 kBtu/hr unit with a 15-year savings of $1,200, not including ancillary maintenance related savings. Across the state the annual savings would be 2.10 kWh per square foot. The analysis showed a benefit-to-cost ratio of 1.7.

Program and Project Experience Notes

- Additional energy codes are considering FDD requirements. The California directive for FDD requirements is written using simple requirements and leaves the technical details to the vendor.
- FDD fault monitoring requires attention by the owner, vendor, or trade ally. As FDD becomes more standardized and simpler, the number of vendors providing services should increase.

Inside - Repair		Repair	Retrofit	Replace
	Outside			
	Inside	●		

Cost Effectiveness	High
Cost	Low
Savings	Mixed

Inside Equipment

Fixing Thermostats, Sensors, and Controls

Adjustments to thermostats, sensors and controls are sometimes conducted as part of RTU maintenance outside repair but can be discussed separately as an inside measure. In the course of work the contractor reviews and corrects deficiencies in the indoor HVAC control components in the building. This includes:

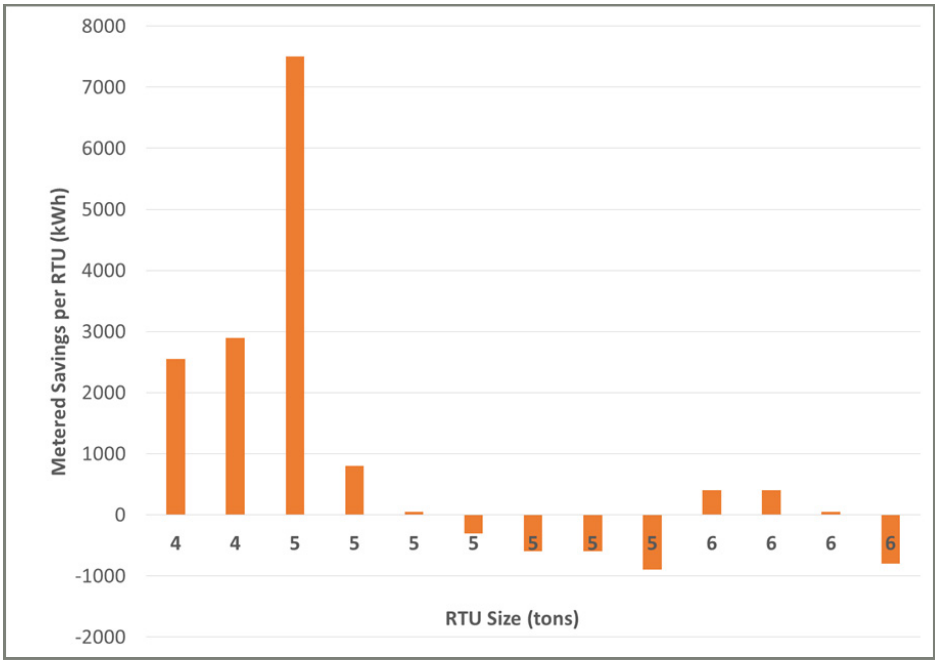
- Reaffirm correct thermostat schedule settings and connect existing 2-stage controls.
- Calibrate CO_2 and temperature sensors
- Reaffirm or adjust sensor or thermostat placement

Savings and Costs

It sounds very simple but savings from inside repair of thermostats and controls can be significant. For example, a change that enables a second stage compressor or eliminates unnecessary heating and cooling at night can produce huge savings. However, these controls adjustments can have a greater distribution of impacts, i.e. several sites with no impact, then one with a large impact. Couple this with the lack of a code baseline that directly addresses the utilization of these components and it can be difficult to calculate programmatic savings.

Figure 4 shows some metered savings data for controls changes to RTUs from the BPA territory. Note how savings from controls changes can be quite significant but more often are modest and sometimes can even be negative. Negative savings can result from the contractors making minimal to no changes or repairing nonoperational equipment.

Figure 4: Metered savings from RTU Thermostat upgrades



Program and Project Experiences

- If possible, combine as part of outside repair RTU Maintenance program
- Complete replacement of thermostats should be considered in favor of newer technology. See “Control Upgrades to Inside Equipment” in the next section.

RETROFIT

Advances in retrofit components have come to market that can enhance energy efficiency in RTU performance. Retrofits of inside and outside equipment fall into three general categories covered in this section:

1. **Control Upgrades to Outside Equipment** – i.e. upgrading and adding onto the RTU controls (both inside and outside) to improve operational efficiency and increase utilization of outside air.
2. **Control Upgrades to Inside Equipment** – improved thermostats and indoor controllers.
3. **RTU Upgrades** – modifying the physical characteristics or adding a component to improve the physics of the RTU cooling cycle. For example, adding evaporative measures to improve RTU efficiency in hot dry climates.

Cost Effectiveness	Medium
Cost	Medium - High
Savings	High

Control Upgrades to Outside Equipment

Controls: Outside Retrofit		Repair	Retrofit	Replace
	Outside		●	
	Inside			

Retrofitting RTUs with the latest advanced control strategies can result in significant energy (up to 35%) and cost (up to 38%) savings from reductions in the fan, cooling and heating energy use.[3] Building codes often require that the supply fan on packaged units operate continuously when a building is occupied to meet ventilation needs. Over 90% of the packaged units in the field have constant-speed supply fans. Because the fan is on continuously, and the compressors operate intermittently under most conditions, fan energy consumption can be greater than compressor energy consumption. It is not uncommon to see packaged units in ventilation mode for 40% to 60% of the time in any climate[4].

Outside equipment control products for this guide are split into two groups based on the extent of their features and thus on the cost to adopt this strategy:

1. Advanced Variable Speed Controllers - extensive features including varying the fan speed, differential enthalpy economizer, fault detection and diagnostics (FDD) two-stage capacity control, and Demand Control Ventilation (DCV). Costs upward of $3,000
2. Enhanced Economizer + Controllers – focused on outside damper control, differential dry-bulb economizer, simplified FDD and fan cycling. Costs as low as $250

Advanced Variable Speed Controllers

Advanced variable speed controllers have the ability to control the supply fan, damper position, provide advanced control sequences, provide

3. PNNL, December 2011 Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning with Gas Heat.

4. Same reference as above (IBID)

RTU Variable Speed Drive Controllers

Digi-RTU courtesy of Bes-Tech

Catalyst courtesy of Transformative Wave

These two controllers are currently market available and have slightly different approaches to achieving control changes

FDD and, in one product, vary the speed of the compressor itself. These products are correspondingly more expensive.

A contractor or trade ally installs the controller and commissions the new operation of the system. New controllers with big impacts are emerging, but very few programs currently have incentives for these specific devices.

A small fraction of utilities (around 8% of programs) incentivize DCV and many incentivize variable speed controls for large fans and pumps. These controllers would qualify for these incentives but the amounts offered by programs do not reflect the level of savings achievable by the devices. With cost per unit high (on the order of $3000) the cost-effectiveness of the advanced controllers are best for units approximately 7 tons and higher.

Enhanced Economizer + Controllers

The two products in the second cohort are less expensive and provide damper control and DCV with some FDD and commissioning features. These products are much more applicable for the large number of RTUs that fall into the smaller, near 5-ton, size range.

The market is interested in these products and contractors are becoming comfortable with the practicalities of their installation and use. The products are still considered emerging technologies, and though they are rapidly becoming ‘off the shelf’ there may still be evolving improvements. For example, integration with existing building automation systems (BAS) may not be streamlined.

Table 4: Controls Products for Small RTUs (5 tons and less)

Economizer upgrade-Economizer and DCV			
Jade	Honeywell	Enhanced economizer function. RA DCV, basic FDD	honeywell.com
Zip	Belimo	Enhanced economizer functionality- 10-15% more than Jade	zipeconomizer.com

Functionality:

- Better Damper Control
- DCV- Fan cycling
- FDD
- Integrated with existing thermostat

The Honeywell Jade and Belimo Zip are an order of magnitude less expensive ($250–$700) than the advanced variable speed control options. There is limited savings data available at this time, but research by PECI indicates that DCV accomplished by fan cycling can be as effective as using variable speed. Notably, the California RTU programs Control Quality Maintenance and Advanced Control Programs are considering the direct coverage of these controllers as part of their repair program scope. This implies the cost-effectiveness of these more focused products is very high.

Savings and Costs

Advanced variable speed controllers savings are significant with current studies showing verified savings results of 30–50% as shown in Table 5[5]. This does not include savings that might be associated with FDD capabilities in the units. Several additional tests are completed or underway, and several utilities are considering adding incentives for these controllers. Costs, as referenced earlier, of the advanced variable speed controllers is on the order of $3,000 per unit while the more modest enhanced economizer and controllers are approximately $250-700.

Table 5: Early Results Look Good (2011-2012)

Testing Organization	Product	Savings/Payback	Sample size
Omaha Public Power District (OPPD)	Digi-RTU	41% kW, 52% kWh 20-60% range	30 RTUs
Snohomish County PUD	Catalyst	48% kWh 17-18% kW, ~20%kWh	1 restaurant 2 drugstores
TES Engineering	Enerfit	2 to 3.5-year payback	9 of 11 buildings 2 of 11 buildings
National Renewable Energy Lab	simulation	29-75% annual fan electricity savings	16 U.S. cities, big-box retail
Pacific Northwest National Lab	simulation	15-56% annual HVAC energy savings	16 U.S. cities, 4 buildings types

Results of Energy Savings Reviews of Advanced Controllers (2011-2012)

5. E Source 2012

The Consortium for Energy Efficiency has dedicated a variable speed controller working group to provide program collaboration with these products.

Program and Project Experiences

- Be aware of constraints that might affect savings, such as:
    - During a pilot project the controller may increase ventilation air to meet standards resulting in higher energy use.
    - If the RTU is already running in 'auto,' meaning the ventilation air only runs with heating and cooling, as opposed to continuously throughout the occupied period, the savings may be smaller.
- Specifics of the advanced controller best practice control approach are articulated well in PECI's Premium Ventilation Package specification and reports.[6]
- The advanced controllers provide some monitoring capabilities that may interest owners with a split-incentive issue (i.e. tenants are paying RTU energy bill). Owners appreciate the ability to keep track of equipment which can result in reduced maintenance costs.
- The advanced controllers provide some monitoring capabilities that may interest owners with a split-incentive issue (tenants paying the energy bill) as they will be able to identify equipment maintenance issue that fall to their side of the lease.
- As with most programmatic offerings contractor training should be part of a program. Be aware that advanced controller vendors may have a certification plan requiring contractors to pay a one-time fee to become licensed installers.
- Outside control retrofit products will also enable FDD (discussed in Repair).
- Integration with an existing building automation system (BAS) can be an issue that trips up implementation. These products are working on ways to improve integration with legacy control systems.

Inside Retrofit: Controls		Repair	Retrofit	Replace
	Outside			
	Inside		●	

Control Upgrades to Inside Equipment

Cost Effectiveness	Medium-Low
Cost	Medium
Savings	Medium

Wireless Web-based Thermostats and Sensors

Standalone thermostats still control many RTUs. A standalone

6. Premium Ventilation Package for RTUS pdf, ASHRAE Conference Paper, Ventilation Retrofit Opportunities pdf (Reid Hart)

thermostats that may or may not be programmable but is not connected to a central building automation system and cannot be remotely monitored and changed. Networked approaches allow for better management of settings and additional functionality and can also incorporate remote monitoring, demand and occupancy controlled ventilation, and other advanced control concepts.

Existing RTU programs often provide incentives for programmable thermostat retrofits (18% of programs surveyed) and several vendors have emerged with products that offer different levels of capabilities and monitoring options. With many small businesses still using residential-type analog style thermostats, moving to a programmable upgrade is a first step toward managing energy use.

Table 6: Indoor control solutions

Name	Vendor	Description	Link
DreamWatts	Makad	Smart Thermostat, web-based scheduling, wireless mesh communications, DR, DCV	makadenergy.com
Eco-Factor	KMC	Smart Thermostat, web-based scheduling, DR, DCV, learning algorithm	ecofactor.com
EcoBee	Alerton	Smart Thermostat, web-based scheduling, DCV	ecobee.com
Emme	Emme	Smart Thermostat, web-based scheduling, wireless mesh communications, DR, DCV	getemme.com
ezeSystem	ezeSystem	Smart Thermostat, web-based scheduling, kWh/kW monitoring, DR, DCV, prepayment	ezesystem.com
Telkonet	EcoSmart	Smart Thermostat, web-based scheduling, smart recovery algorithm, DR, DCV	telkonet.com
Nest	Nest	Smart Thermostat, web-based scheduling, wi-fi communications, learning algorithm, DR, DCV	www.nest.com

Savings and Costs

The cost of these devices is decreasing as the technology matures. Current costs are approximately $300 per thermostat, not including annual monitoring costs.

Savings benefits are highly variable and not well understood. Additional research is needed to establish realistic savings estimates for this measure. The measure offers significant owner/manager non-energy benefits by providing a platform for occupants to manage their facility as well as a way for the owner to remotely monitor the asset. The analysis of this type of system requires whole-building level analysis that will reveal the true impact of the measures.

Program and Project Experiences

- Programs should highlight the non-energy benefits of control retrofits for owners and managers. The ability to monitor their asset remotely can be a determining factor in which technology and/or equipment is ultimately chosen, and the resulting incentive is an added bonus.

Outside Retrofit: RTU Additional Equipment		Repair	Retrofit	Replace
	Outside		●	
	Inside			

Cost Effectiveness	*Medium-Low
Cost	Medium
Savings	Medium

** excludes humid climates*

RTU Upgrades: Adding Equipment

Adding equipment to an RTU or modifying the unit's existing equipment can improve its efficiency. Some RTU upgrades such as motor replacements can improve the refrigeration cycle efficiency. Adding an economizer allows the RTU to provide cooling without using the compressor when outdoor air conditions permit. Some RTU upgrade measures rely on evaporative cooling and are limited to certain climates. Outside retrofit augmentation measures include:

- Air-Side Economizers
- Electrically Commutated Motors (ECM)
- Evaporative 'Sidecar' Unit
- Evaporative Condenser Unit

Cost Effectiveness	*Medium
Cost	Medium
Savings	Medium

** excludes humid climates*

Air-Side Economizers

The economizer controls an outdoor air damper to allow the unit to use outdoor air for cooling air when the conditions are appropriate. The technology is well understood and 21% of major utility programs surveyed have incentives for retrofitting economizers. In addition, economizers are required by some energy codes due to the energy savings potential. When considering an economizer installation one must consider the outside air conditions through the year to optimize the savings potential. For example the Northwest, Northern California and many mid-west cities have abundant outdoor temperature hours that meet the indoor design temps without excessive humidity so that 'free cooling' can be provided through an economizer. More southern and humid locations may not be as well suited. Cases in which economizer installation or operations do not match the design intent are notorious, and in those cases savings may not materialize as expected. An implementation and operational strategy needs to be part of any efficiency program addressing this technology upgrade to RTUs.

Cost Effectiveness	Medium-Low
Cost	Very High
Savings	High

Electronically Computated Motors (ECM) – Replacement of Supply Fan Motor

The supply fan is the primary driver for blowing cooling and ventilation air into the space. Typically the supply fan operates continuously throughout the day and can be a large energy user. ECMs are DC motors that use a permanent magnet and consequently can get the same amount of airflow out of a much lower power level than an AC motor. Almost no efficiency or green building programs incentivize ECMs for RTUs specifically though many provide incentives for ECMs in any equipment, such as RTUs, residential furnaces and air handlers or commercial refrigeration equipment. They are also significantly more efficient at the common part-load operating conditions (see Table 7).

Table 7: RTU Supply Fan Motor Types

Typical Motor	Electronically Commutated Motor
AC Induction motor	DC motor
Typically only 40-50% efficient	>70% efficiency
As low as 15-20% efficient at part load	Efficient at part load due to efficient speed contro
Primitive (on/off) speed control	Typically variable speed control due to electronic controller

Cost Effectiveness	*Low
Cost	Very High
Savings	High

** excludes humid climates*

Evaporative indirect cooler that is integrated as a sidecar with an existing 5-ton RTU

Evaporative 'Side Car'

Though still an emerging methodology, the Northwest Energy Efficiency Alliance (NEEA) has conducted several research projects on using indirect or indirect/direct evaporative cooling units in conjunction with existing RTUs. The result is evaporative cooling as a first stage with the ability to use the RTU compressor as a second stage if necessary.

A key benefit of the use of an evaporative first stage is the potential to reduce the run time of the compressor which will prolong its life and provide real financial return to the owner, in addition to energy savings to both owner and tenant. In the NEEA study the side-car unit used an average of just 2 kW, which was approximately 50% less energy compared to the unit prior to the retrofit addition of the side-car. Because the RTU compressor remains the stage-two cooling source, the peak energy for pre- and post-retrofit were similar.

Cost Effectiveness	*Medium-Low
Cost	Very High
Savings	High

** excludes humid climates*

Evaporative Condenser Pre-Cooling

An evaporative process can also be used to cool air that surrounds the outdoor coil (condenser) since the refrigerant loop has improved efficiency at cooler operating conditions. The device is attached to the outside of the RTU and evaporates water that chills the air going to the outside coils.

Several products exist in the market, and some efficiency programs have evaporative unit incentives, though no exact data is available.

Savings and Costs / Program and Project Experiences

Economizers. Economizer retrofits are well understood and commonly integrated into efficiency programs where not already required by code. The code and the program adoptions indicate the economizer saves energy within the constraints of these policies and programs. Some analysis indicates that the savings are most significant in heavily used spaces with high internal loads. Integrating an economizer retrofit in conjunction with an enhanced economizer outdoor controls retrofit is a good way to optimize savings and costs.

ECMs. The savings comes from reducing the high portion of electrical energy use by the supply fan in RTUs. ECM motors are essentially twice as efficient as a standard motor. Little data exists for ECM retrofits on RTUs, but the approach appears to have great savings potential, especially when coupled with an advanced controller retrofit. Costs are estimated at $350-500.

Indirect/Direct Evaporative Side-Car. Savings from preliminary field tests are high, on the order of 50–60% for a 5-ton rooftop unit. At least one vendor has a product that is price competitive with outdoor controls retrofits. Total installed costs and associated maintenance costs are still being evaluated. Details regarding water usage and maintenance costs are also still forthcoming but will certainly impact the cost-benefit equation.

Evaporative Condenser Pre-Cooling. Savings are demonstrable and significant, with cost-effectiveness best for units approximately 10 tons and larger. Clearly this is a climate-specific technology best suited for hot dry climates.

More information on RTU equipment retrofits is available from the **Western Cooling Efficiency Center at UC Davis**.

REPLACE

Decisions by owners to replace units at the end of their useful life or due to unexpected failure usually involve a like-to-like replacement in terms of equipment size and type (often the same brand as well). Even with a replacement there can be a significant increase in energy efficiency just through the natural evolution of building energy codes requiring increased RTU minimum efficiency levels.

The most common approach for efficiency programs is to influence the selection of equipment so that the new RTU is well beyond the base code level and includes some of the control options discussed earlier. In some cases the building owner or a design firm may have reason to consider a complete redesign of the HVAC system utilizing new equipment and a new strategy. These are discussed below; for example, a radiant heating and cooling system coupled with a Dedicated Outdoor Air System (DOAS).

High Efficiency RTUs

Cost Effectiveness	Medium
Cost	High
Savings	High

Outside Replacement: High Efficiency RTU		Repair	Retrofit	Replace
	Outside			●
	Inside			

Many efficiency programs incentivize new RTUs. These typically offer a per-ton incentive for units with higher efficiency as measured by AHRI ratings like EER or SEER. CEE provides a helpful, and frequently utilized, organizational method by establishing tiers of performance. DOE has also launched, through its Better Buildings Program, an **Advanced RTU Campaign** with many resources and analysis sources that can support efficiency programs.

The options for replacing an existing standard RTU with a similar higher efficiency unit have increased, primarily driven by updates in national minimum energy code efficiency requirements and manufacturer enhancements. New replacement RTUs have many new efficiency features available including variable-speed fans, direct drive, embedded remote communication capabilities and expanded fault detection and diagnostics. These capabilities come at an added cost over a 'code-minimum' RTU.

Savings and Costs:

Projecting savings in a specific climate zone can be done with the **PNNL calculator** which estimates savings for a like-for-like RTU replacement and a corresponding change in the fan controls.

The high performance units are capable of manipulating the fan and its associated energy use in a way similar to the Variable Speed RTU Controllers discussed above. The Department of Energy's High Performance Rooftop Unit Challenge resulted in several manufacturers achieving an RTU with a SEER of 18. This is a 22% improvement over Tier 2 of the CEE Performance Tiers. NBI recently field tested the DOE

Challenge high performance units and estimated a 35–40% savings at a particular installation over a code-minimum RTU. Notably, NBI analysis found that the savings for this unit would be 3280 kWh per year ($328 per year at $0.10 per kWh). The incentive, however, based on the Northwest Standard Technical Resource manual, would credit the installation with only 1758 kwh and $175.80 of dollar savings. This is an example of where the efficiency program needs to advocate for the savings attribution from the most current and efficient products.

Program and Project Experiences

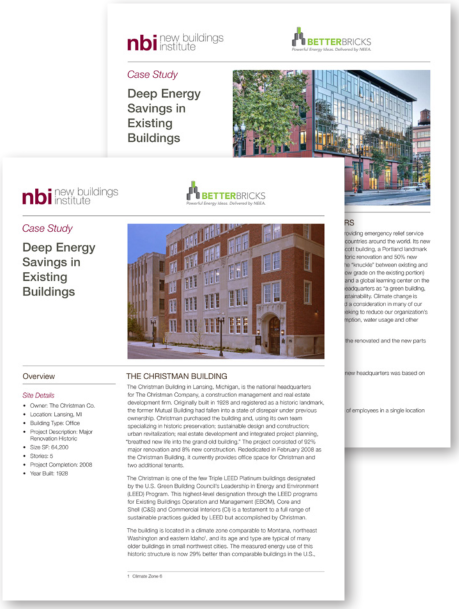
- Programs that incentivize changes in RTU EER are widespread. Incentives are paid in dollars per ton of cooling for units that exceed code requirements for RTU efficiency. These can be tied to the CEE performance tiers that specify AHRI performance requirements for certain groups of unitary air conditioners and heat pumps.
- Programmatically the savings can be accessible if the high performance RTU that replaces an existing RTU is equipped with controls that can perform the necessary operations like variable speeds, DCV, FDD and remote monitoring.
- Incentives may not be claimed by RTU purchasers if they are too low and the application process is tedious.
- Advanced units that include advanced control features may result in higher savings than are reflected by the AHRI ratings.

Cost Effectiveness	Medium-Low
Cost	N/A
Savings	N/A

HVAC System Redesign

Outside and Inside Replacement: Redesign		Repair	Retrofit	Replace
	Outside			●
	Inside			●

Some leading building owners may want to consider a 'deep retrofit' approach to solving RTU energy use and comfort-related issues or to pursue green and/or efficiency targets. Recently a few case studies of deep retrofits of older 1970s and 1980s buildings have emerged demonstrating that even existing buildings can approach net-zero energy use, and the HVAC redesign is a major part of achieving this low-energy target. Clearly this is not the standard method to address RTU efficiency, but these leading-edge buildings and related media and market attention are a growing part of building renovations. These types of buildings typically employ a new strategy of HVAC that separates heating and cooling from ventilation air among many other aggressive savings strategies to mitigate losses from the envelope and internal heating from equipment.



New construction or major renovation programs may apply more specifically in these deep retrofit cases. Also, many have custom programs that pay fixed incentives per kWh or therm based on measurement and verification (M&V) results. This further drives the incentive for a major redesign to include advanced monitoring rather than simply replacement of RTUs. Some existing RTU programs have incentives for air- and ground-source heat pump RTUs that might replace existing RTUs, resulting in savings. Radiant-based systems (radiant heating, cooling and chilled beams) is another highly efficient redesign system found primarily in the best practice low- and zero-energy buildings. These systems completely eliminate duct work and the majority of fan energy in the HVAC system and provide ventilation through a Dedicated Outside Air System (DOAS) often coupled with energy recovery. Although the radiant systems require a pump for circulating the chilled or heated water, moving water with a pump is 7 times more efficient than pushing air with a fan.

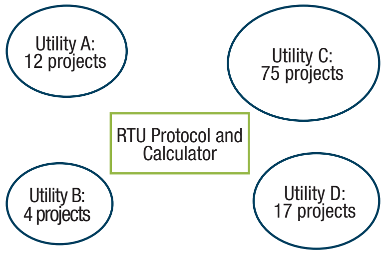
Savings and Costs

Savings and costs are highly variable in deep retrofit projects. A report on **A Case for Deep Retrofits** highlights the technology changes, business rationale and costs.

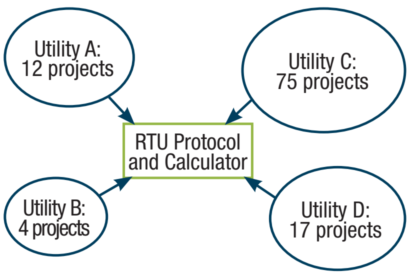
Program and Project Experiences

- New construction programs apply more effectively to deep retrofits
- Alternative financing models may be available in this emerging industry

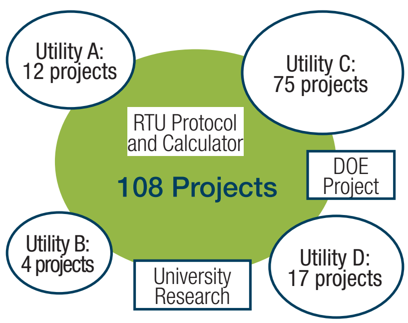
Figure 5: Caption Shared Analysis Methods and Results Leverage Program RTU Projects



Each program calculates savings...



...and merge the dataset



Efficiency Programs And Measuring RTU Savings – Two Standard Methods

RTU pilot projects are frequently conducted by energy efficiency/green building programs. The results of these investigations are sometimes published in public forums, but often sharing is limited to savings percentages and/or kWh or kW realized. With RTUs there are many variables that can impact savings results.

A big one is local climate. An RTU program pilot in Arizona will achieve higher kWh, and percent savings than one in Vermont even if the exact same RTU and measures are used simply because there are so many more hot days. The distribution of temperatures will also impact the savings.

The use of a standard analysis and data adoption protocol with a weather-normalized format allows measure impacts from energy measure field projects to be shared across locations. The result is a leveraged data set that can benefit many interested parties and support programmatic efforts.

NBI has two standardized protocols to harmonize analysis at both the RTU and whole-building levels. These are:

- RTU Savings protocol and calculator (RTU Savings Calculator)
- Whole building savings protocol and calculation tools (FirstView® and EZ Sim)

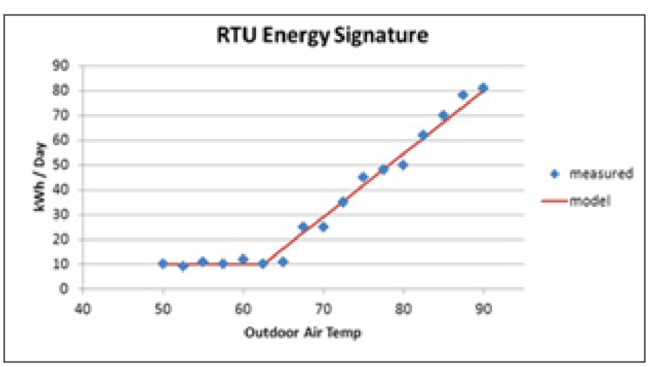
RTU Savings Protocol and Calculator

In conjunction with input from the Regional Technical Forum (RTF) in the Pacific Northwest, NBI has developed a standardized protocol and spreadsheet calculator for assessing the before and after savings attributable to certain types of RTU measures. This protocol can inform and facilitiate analysis of pilot project results and programmatic evaluations to standardize the data that is provided to regulators and bolster programs total benefit assessment.

An example of a plot used by the protocol is shown in Figure 6, and Table 8 describes what measures are suited for this analysis.

Figure 6: Example Plot of Savings from the RTU Savings Calculator.

Table 8: (right) Analysis Measures with the RTU Savings Calculator



Savings Calculator: Retrofits and Repair Types

- Physical repair measures
  - Dampers, airflow changes drive adjustments
- Operational repair measures
  - Set points, schedule, and economizer adjustments
- Maintainance measures
  - Coil cleaning, filter changes, refrigerant charge
- Equipment upgrade measures
  - Supply fan, controls, compressor change, etc.

EZ-Sim/FirstView® Whole Building Savings Protocol and Calculator

A whole-building protocol is needed when changes to the building impact more than one RTU or require a complete RTU redesign or changes to the indoor settings. NBI has two related whole-building analysis tools for this purpose. Below are a graphic and a table describing when this can be used.

Sometimes changes made to a commercial building RTU are drastic or involve RTUs that serve overlapping zones. Using a whole-building analysis method helps to evaluate the energy change and also preserves the results in a weather-normalized fashion.

Table 9 provides a brief summary of the requirements of each method. Through standardized analysis results can be shared and applied between climate zones.

Figure 7: Example of EZ-Sim/ FirstView Predicted vs. Actual Whole-Building Energy Billings

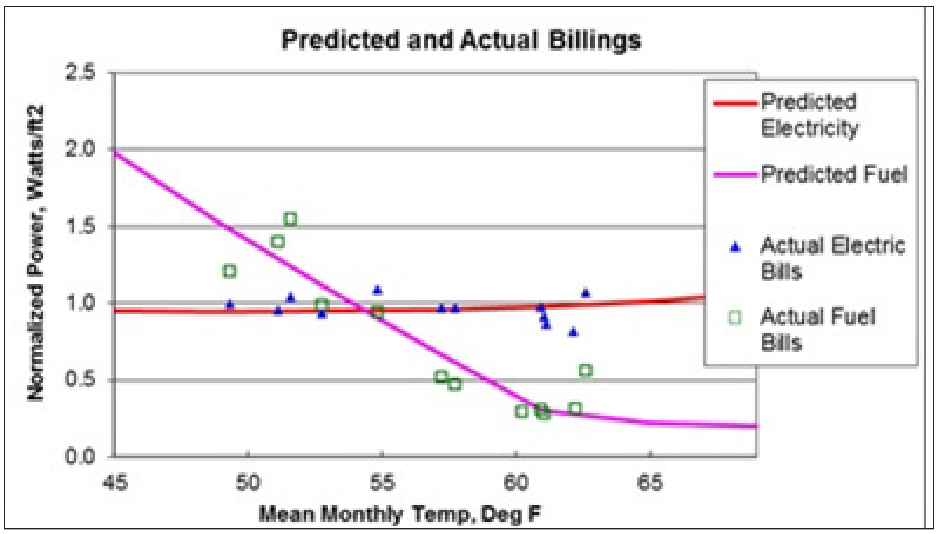


Table 9: Characteristics of the RTU Savings Calculator and EZ-Sim/ FirstView

	RTU Savings Calculator	EZ-Sim/FirstView
Boundary of measurement	RTU total electrical energy/power	Whole-building total fuel usage
Fuels needed	Electricity only	Electricity and all fuels
Data frequency	One-minute interval	Monthly billing data
Monitoring period	4 weeks of ‘pre’ data and 4 weeks of ‘post’ data	12 months of ‘pre’ data and 12 months of ‘post’ data
Result	Annual electrical savings for measure	Normalized energy savings at site for measures

RTU Coalitions And Programmatic Efforts

Collaboration is the key to the future success and expansion of RTU energy efficiency measures. Utilities should seek to align their RTU and HVAC programs with national efforts to maximize the benefit of dollars spent within each efficiency program in its quest to establish effective and productive programs. Participants are the drivers for harmonized analysis of measures, streamlining and simplifying of RTU program offerings, and accurate assessment of incentives. The coalitions and resources listed here can provide efficiency programs with information such as best practices, energy analysis methods and emerging RTU trends. This RTU primer is intended as one such resource to guide the current and next-stage planning of HVAC programs and direct the reader regarding key areas for energy saving opportunities and locations for futher information.

Western HVAC Performance Alliance www.performancealliance.org

The Western HVAC Performance Alliance (WHPA) is a fusion of HVAC, energy efficiency, facility, and property management organizations whose decision-maker-level appointees work with one another, with utilities and with government to curb energy waste.

Department of Energy Advanced RTU Campaign www.advancedrtu.org

ARC is a recognition and guidance program designed to encourage building owners and operators to take advantage of savings opportunities from high efficiency RTUs. This effort is a collaboration between ASHRAE and RILA, with the U.S. Department of Energy providing technical support to campaign participants (through the Better Buildings Alliance and the Federal Energy Management Program). Organizations that do not directly own or manage buildings are encouraged to join the campaign as supporting partners.

Consortium for Energy Efficiency www.cee1.org

For over twenty years, CEE has been influencing markets to accelerate uptake of increasingly efficient goods and services. Members still find value in working together in a business environment characterized by increasing emphasis on energy efficiency, higher baseline standards that reduce savings potential, and larger savings goals.

The CEE role is not to develop or implement the programs delivered at the local level, but to influence national players—manufacturers, stakeholders, government agencies—to maximize the impact of efficiency programs.

Other Resources:

Energy Center of Wisconsin www.ecw.org

The Energy Center is a nonprofit organization dedicated to wise use of energy resources. It acts as a change agent, inspiring evolution in how the market and policymakers approach energy efficiency.

ASHRAE 90.1
https://ashrae.org/standards-research--technology/standards--guidelines

ASHRAE 62.1
https://ashrae.org/standards-research--technology/standards--guidelines

Western Cooling Efficiency Center www.wcec.ucdavis.edu

The WCEC engages in primary research, innovation, laboratory testing, field demonstrations, education, outreach, and advocacy related to climate appropriate cooling technologies.

Pacific Northwest National Laboratory www.pnnl.gov/uac/

PECI Inc. www.peci.org/programs/commercial/hvac

Lawrence Berkeley National Laboratory – Duct Sealing
http://ducts.lbl.gov

About NBI and Advanced Buildings®

nbi new buildings institute

New Buildings Institute is a nonprofit organization working to improve the energy performance of commercial buildings. We work collaboratively with commercial building market players—governments, utilities, energy efficiency advocates and building professionals—to remove barriers to energy efficiency, including promoting advanced design practices, improved technologies, public policies and programs that improve energy efficiency. We also develop and offer guidance to individuals and organizations on designing and constructing energy-efficient buildings through our Advanced Buildings suite of tools and resources.

advanced buildings

Energy performance solutions from NBI

Advanced Buildings is New Buildings Institute's suite of technical tools and resources developed to help design teams create high performance buildings that stand out for their energy efficiency and healthy environments. In addition to the development of tools and guidance, Advanced Buildings offers additional educational resources such as case studies, webinars, research findings and market integration tools for driving high performance buildings.